Fourier

What did you learn??
Perception

- Can pick out one frequency
1. The pulse on the left is moving right, the pulse on the right is moving left. What do you see when the pulses overlap?

Adapted From Pollock at CU course: Physics of Sound and Music for nonscientists there are a total for 4 slides for this
http://www.physics.nyu.edu/~ts2/Animation/waves.html
2. If these two waves were moving through water at the same time, what would the water look like?

D
Echolocation
Sound bounces off of different materials
Listen for echoes

- Echolocators listen for the sounds bouncing back
- Most produce their own sounds (such as clicks) and listen for them to come back.
- People do this subconsciously
Results of Wednesday’s Project:

- How many times did someone grab an object successfully?
- What was hardest location?
- Was everyone equally as good?
- Could you tell the short side of the room?
Locating sounds
Listen for the delay

- The delay tells the brain how far away an object is.

- If one ear hears it first, then it knows the object is on that side.
Acousticians

- Animal bioacousticians
- Underwater acousticians
- P & P: Physical and Psychological
- Audiologists
Acousticians

- Musical Instrument Design
- Speech scientist
- Medical acoustics

- Architectural acousticians
  - Concert Halls
  - Vibration (ie. Bridges)
Audi Sound Engineers

How many different types of acoustics jobs are included in this video?
MIT Museum
How many different types of acoustics jobs are included in this video?

- Musicians
- Marketing - Sound Designers
- Mechanical Engineers
- P &P (psychological)
- ....

Main Point: Audi is trying to create a distinct sound that is associated with their brand name and the marketing which goes into their product. Their ability to reach their goal depends on how well their audio engineers and sound design team understand basic principles in acoustics.
Bob Coffeen

- 2012 Acoustics Education Prize
  University of Kansas
  School of Architectural Design and Planning
  - Acoustics is often not required
PLEASE NOTE THAT I WEAR HEARING AIDS…
AND SO WHAT!

I BEGAN USING HEARING AIDS SEVERAL YEARS AGO
BECAUSE I WAS HAVING SOME PROBLEMS
UNDERSTANDING STUDENTS IN MY CLASSES

Slides courtesy of Bob Coffeen
THESE AUDIOGRAMS INDICATE THAT MY HIGHER FREQUENCY HEARING IS NOT DOING TOO WELL.

MAYBE FLYING NOISY LIGHT AIRCRAFT FOR MANY YEARS, MOST OF THE TIME WITHOUT EAR PROTECTION

A COMPANY BUS AND TRUCK
LET'S TAKE A LOOK AT SOME FREQUENCY STUFF AND ITS RELATION TO SPEECH INTELLIGIBILITY

HEARING FREQ. RANGE FOR YOU YOUNG GUYS

HEARING FREQ. RANGE FOR SOME OF US "MATURE" GUYS

PIANO

TWO Cs ABOVE MIDDLE C

MIDDLE C

YOUR STEREO SYSTEM (PERHAPS SOME WISEFULLY THOUGHTFUL MFR)

NATURALNESS

VOWELS

SPEECH CONSONANTS

INTELLIGIBILITY

FULL RANGE SPEECH

SPEECH AT 250 Hz AND BELOW

WHAT IS AN OCTAVE?

25% OF SPEECH INTELLIGIBILITY IS IN 2000 Hz OCTAVE BAND

OCTAVE BAND CENTER FREQUENCY - Hz
Main Entry: **octave**

Pronunciation: 'ək-tiv, -tiv, -"təv

Function: **noun**

Etymology: Middle English, from Medieval Latin *octava*, from Latin, feminine of *octavus* eighth, from *octo* eight -- more at **EIGHT**

Date: 14th century

1: an 8-day period of observances beginning with a festival day

2 a: a stanza of eight lines: **OTTAVA RIMA** b: the first eight lines of an Italian sonnet

3 a: a musical interval embracing eight diatonic degrees b: a tone or note at this interval c: the harmonic combination of two tones an octave apart d: the whole series of notes, tones, or digits comprised within this interval and forming the unit of the modern scale e: an organ stop giving tones an octave above those corresponding to the digits

4: the interval between two frequencies (as in an electromagnetic spectrum) having a ratio of 2 to 1

5: a group of eight
LET'S BACK UP A BIT...

WHAT IS SOUND?

One definition is...

Wave motion consisting of very small changes in air pressure which cause our eardrums (tympanic membrane) to "wiggle" (vibrate)
What two parameters must be identified to describe any sound?

Frequency (Pitch)
Amplitude (Intensity...Pressure)
How do we describe frequency?

Repetition rate in
Cycles per second
Hertz (Hz)
How can we describe the frequency content of a sound?

By determining the sound pressure level within an octave frequency band or subdivisions of an octave band such as one-third octave band, one-sixth octave band, etc.
The center frequencies of octave frequency bands have been standardized and are accepted the world over. The upper and lower frequency limits can be determined as follows:

Upper limit = (center freq) $2^{1/2}$ = (center freq) 1.414
Lower limit = (center freq)/$2^{1/2}$ = (center freq) 0.707
THUS FAR WE HAVE TALKED ABOUT OCTAVE FREQUENCY BANDS. BUT, FOR HIGHER RESOLUTION IN DESCRIBING THE SPECTRUM OF A SOUND, WE OFTEN USE ONE-THIRD OCTAVE BANDS...

<table>
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<th>CENTER FREQ. -</th>
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<tbody>
<tr>
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<tr>
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</table>

One-third octave bands are said to be 23 percent bands. The band width is approximately 23 percent of the center frequency.

The Octave Freq Band centered at 250 Hz contains the one-third octave bands centered at 200, 250, and 315 Hz.

Standard Octave Band Center Frequencies are shown in red.

For octave bands the center frequency is multiplied by 2 to obtain the center frequency of the next higher band.

For one-third octave bands the center frequency of a 1/3 octave band is multiplied by \(2^{\frac{2}{3}}(1.26)\) to obtain the center frequency of the next higher band.
Let’s see how we can observe the frequency characteristics of a particular sound

WE’LL LOOK AT MEASUREMENTS FROM THE COMPUTER PROGRAMS
EASERA and systune
1000 Hz octave band extends from about 700 Hz to 1400 Hz.

This graphic indication on the analyzer shows that the sum of all sound energy in the 1000 Hz octave band is at a level of 80 dB.

We haven't yet defined dB (decibel) but we will do so soon.

Octave band center frequency doubles for each higher frequency octave band.
500 Hz OCTAVE BAND EXTENDS FROM ABOUT 560 Hz TO 700 Hz

WIDTH OF BAND IS 1/3% OF CENTER FREQUENCY, IN THIS CASE 550 Hz.
The graphic indication on the analyzer shows that the sum of all sound energy in the 500 Hz 1/3 octave band is at a level of 80 dB, with 23% of center frequency, in this case 114 Hz.
Noise is often used as a test signal or for other uses.

What are the frequency characteristics of pink noise and white noise?
LISTEN TO PINK NOISE

PINK NOISE – EQUAL ENERGY IN EVERY "CONSTANT PERCENTAGE" BANDWIDTH...OCTAVE BAND, 1/3 OCTAVE BAND, ETC...
APPEARS "FLAT" (OR NEARLY "FLAT") WITH FREQUENCY
LISTEN TO WHITE NOISE

WHITE NOISE – EQUAL ENERGY IN EVERY CYCLE...WHEN ANALYZED IN OCTAVE FREQUENCY BANDS THE LEVEL INCREASES WITH EACH HIGHER FREQUENCY OCTAVE BAND BY 3 dB. WHEN ANALYZED IN 1/3 OCTAVE FREQUENCY BANDS THE LEVEL INCREASES WITH EACH HIGHER 1/3 OCTAVE BAND BY 1 dB.

ANALYSIS BY EAGERA ODSTUNE
Frequency Attenuation

• Which travel further – high frequencies or low frequencies?
Dolphins

- Use lower sounds in captivity
- Use higher frequency in the wild

Why?

Whit Au discovered in 1974
Whit's answer

- First of all, absorption losses increase with frequency. So the higher the frequency the more the absorption losses will be for a given range.
- Secondly, the center frequency of the output signals tend to increase with amplitude. In other words, the higher the output the higher the frequency content will be.
- In small tanks, dolphins tend to use much lower amplitude bisonar signals than in large tanks or net-enclosure in open bays. The temporal resolution will be dependent of the bandwidth of the signal - higher bandwidth better resolution. The bandwidth tend to be wider for high frequency signals. So, in many situations, its hard to generalize since the bisonar signals dolphin use depends on the specific situation. Their system seems to be very flexible so dolphins tend to adapt to the situation.